PS&C
Prairie Soils &
Crops Journal

Herbicide Resistance in Weeds: Influence of Farm Practices

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Summary

Weed resistance across the Prairies affects over 10 million acres (4 M ha). The main herbicide-resistant weeds are wild oat, green foxtail, kochia, and chickweed. The risk of weed resistance is greatest in fields with cereal-based rotations and least in fields with forage crops, fallow (summer or green manure), or where three or more crop types are grown, such as cereal, oilseed, and pulse. Risk also is greatest in min-till and no-till systems, possibly due to greater herbicide use and/or more rapid weed seed bank turnover vs. conventional tillage. Large farms (>1,000 acres) have a greater risk of developing resistant weeds than smaller farms possibly due to greater time pressures resulting in less use of integrated weed management practices. Cropping system diversity is the foundation of proactive weed resistance management.

Herbicide-Resistant Weeds: Current Status

Weed resistance monitoring has been routinely conducted across the Prairies since the early 1990s. Comprehensive surveys were conducted in Alberta in 2001, Manitoba in 2002, and Saskatchewan in 2003 totaling nearly 800 randomly selected fields[5]. In addition, nearly 1,300 weed seed samples have been submitted by farmers or industry across the Prairies between 1996 and 2006 for evaluation for resistance. Collected or submitted samples were screened for group 1 (ACCase inhibitors) and/or group 2 (ALS inhibitors) resistance. Twenty percent of 565 fields where wild oat seed samples were collected had a herbicide-resistant (HR) wild oat population (Figure 1). In Manitoba, 22% of fields had group 1-HR green foxtail. Group 2-HR biotypes of sowthistle in Alberta, and green foxtail and redroot pigweed in Manitoba. Across the Prairies, HR weeds are estimated to occur in fields covering an area of over 10 M acres (4 M ha). Of the 1,067 wild oat seed samples submitted by farmers or industry for testing between 1996 and 2006, 68% were group 1-HR (Figure 2), 3% group 2-HR, and 5% group 1- and 2-HR (Figure 3). Of 80 submitted green foxtail samples, 33% were confirmed group 1-HR; most populations originated from southern Manitoba where the weed is most abundant (abundance defined as a composite index of field frequency, field uniformity, and plant density). Similar to the field surveys, various group 2-HR biotypes were confirmed among submitted samples: kochia (Figure 4), wild mustard, stinkweed, cleavers, chickweed, and hemp-nettle.

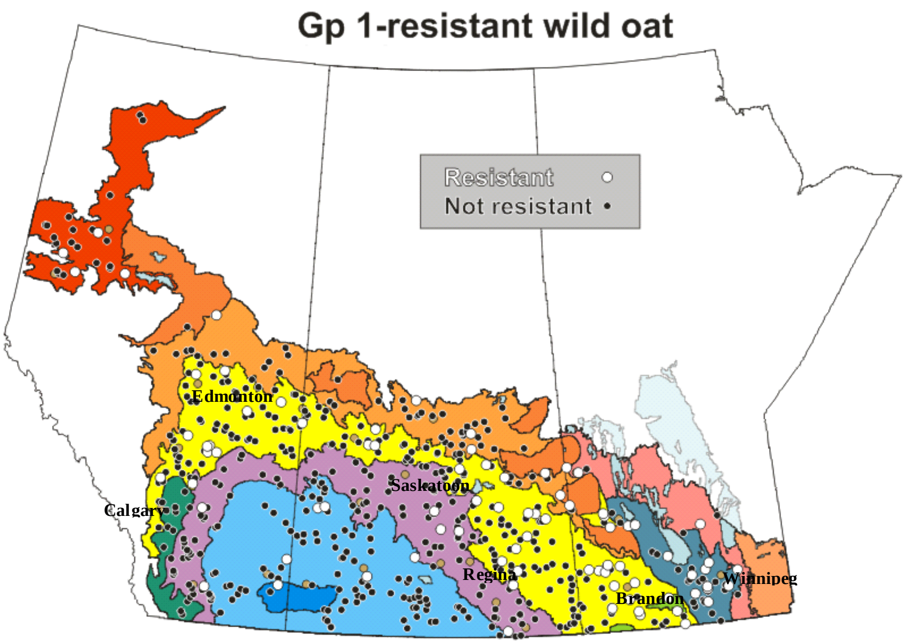

Figure 1. Group 1-resistant wild oat across the Prairies based on surveys conducted from 2001 to 2003[19].

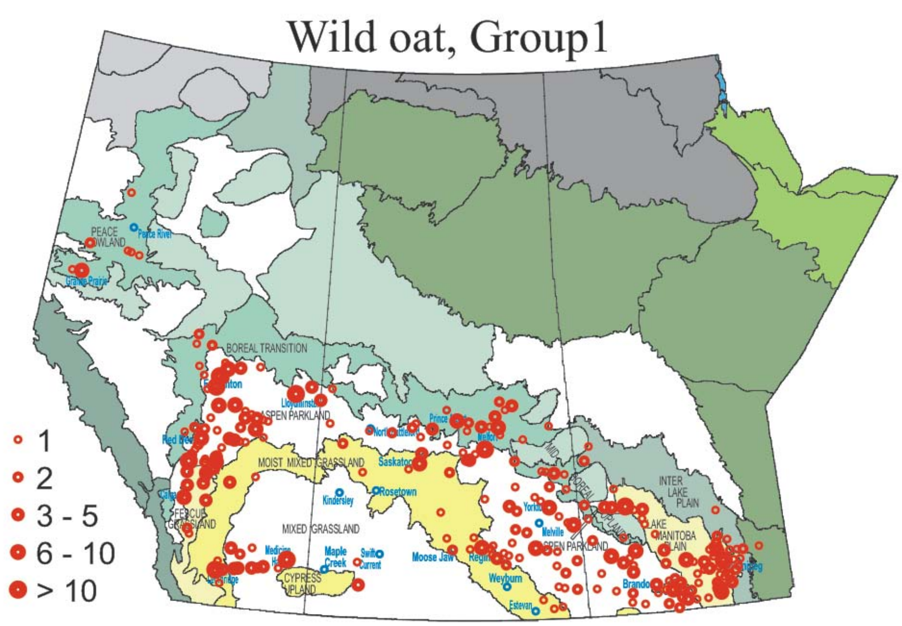

Figure 2. Group 1-resistant wild oat across the Prairies based on samples submitted by farmers or industry for testing from 1996 to 2006 (number of resistance cases per nearest urban location – city, town, or village – is indicated by five range categories)[20].

Awareness by farmers of how agricultural practices can contribute to the development of weed resistance is an important first step in proactively managing HR weeds. The following discussion on risk assessment of weed resistance is based on a survey of 370 fields across the Prairies from 2001 to 2003[6]. Each field was farmed by a different grower, who had completed a questionnaire on management practices used in the surveyed field.

Figure 3. Group 1- and 2-resistant wild oat in a wheat field in Alberta in 2001.

Influence of Farm Practices on Weed Resistance

1. Farm size/type

In the 2001-2003 survey, farmers with farm size greater than 1,000 acres had an increased risk of weed resistance compared to those with farm size less than 1,000 acres, and vice versa. The average farm size in Manitoba, Alberta, and Saskatchewan in 2006 was 1,000 acres, 1,055 acres, and 1,450 acres, respectively[17]. The reason(s) for this association is unclear, although cropping system diversity, tillage intensity, or herbicide use may differ among these farm sizes. Greater time management pressures for farmers with large farms may be negatively impacting the adoption of integrated weed management practices[1].

Figure 4. Group 2-resistant kochia in an imidazolinone-tolerant (Clearfield®) canola field in Alberta in 2001.

A study based on the 1996 Saskatchewan weed resistance survey failed to find an association between the frequency of group 1 resistance in wild oat and type of farming system[20]. Of various farm types (main commodity: cereals, oilseeds, pulses, forages, other crop types, cattle, hogs, or other livestock) examined in the 2001-2003 survey, an association was observed between HR weeds and farms with hogs as the main commodity and source of income. There may be a linkage between weed resistance and application of hog manure (and presumably associated weed seeds) onto land, although no association was detected between weed resistance occurrence and farms with cattle as the main commodity. Farms with hogs as the dominant commodity may be growing mainly feed grains, resulting in low crop diversity and a narrow use of herbicide chemistries.

2. Crop rotation

Triazine resistance in broadleaf weed biotypes in Ontario was associated with crop monoculture[18]. Following the discovery of group 1 resistance in wild oat in 1990 on the Prairies, a farmer survey was conducted in Manitoba in 1994 to identify risk factors for the occurrence of this HR biotype. Farmers from Manitoba townships considered at low risk (based on previous herbicide usage) for the occurrence of group 1 resistance in wild oat had more diversified crop rotations than those from medium- to high-risk townships[8]. Field surveys conducted in Wheatland County in southern Alberta from 1997 to 1999 determined that group 1 and group 2 resistance in wild oat were linked to a lack of crop diversity in the rotations used[4]. Results from that study recommended the inclusion of fall-seeded or perennial forage crops in rotations to slow down the selection of resistance in wild oat.

Based on results of the 2001-2003 survey on the Prairies, the risk of weed resistance was greatest in cereal-based rotations, i.e., cereals comprising four or more crops in the 6-yr rotation (survey year and preceding 5 years), but reduced when perennial forage crops or fallow (summer or green manure) were included at least 1 year in the rotation. However, the occurrence of weed resistance was not associated with the presence or frequency of oilseed, pulse, or specialty (minor acreage) crops in the rotation. Previous research has demonstrated that both annual and perennial forages effectively reduce weed abundance and herbicide use[10, 15, 16]. However, many farmers on the Prairies do not include fallow or forages in their rotation[17] for economic and agronomic reasons.

Those farmers who grew three or more crop types in their rotation (cereal, oilseed, pulse, specialty, perennial forage, fallow) had a reduced risk of weed resistance, which supports results from an earlier study in southern Alberta[4]. Globally, HR grassy weeds are often associated with cereal monocultures[1, 2]. However, this study suggests that even two crop types in the rotation –not including forages or fallow – may not be sufficient to reduce the risk of developing HR weeds.

3. Tillage intensity

Triazine resistance in broadleaf weed biotypes in Ontario was associated with infrequent use of tillage[18]. In addition, group 2-HR wild oat in southern Alberta was associated with min-till and no-till systems[4].

Based on the 2001-2003 Prairie survey, there was an association between weed resistance and tillage intensity. HR weeds were more abundant in no-till and min-till than conventional-till systems. In addition, weed resistance was greater in low soil disturbance no-till than high soil disturbance no-till systems (e.g., seeders using knife openers vs. sweeps, respectively).

Min-till or no-till cropping systems can increase the abundance of specific weed species and may result in greater herbicide use. No-till systems alter the soil microclimate, resulting in cooler soil temperatures at or below the surface due to greater soil moisture levels and greater crop residue on the surface reflecting sunlight relative to that in conventional-till systems. An examination of long-term tillage studies across the Prairies concluded that the abundance of wild oat was not affected by tillage system, while green foxtail was associated with conventional tillage[19]. Weeds with small seeds, such as green foxtail, may be disadvantaged in no-till systems because of lack of reserves necessary for emergence due to conditions created by surface crop residue and lack of soil disturbance. Nonetheless, both wild oat and green foxtail were uniformly abundant across all tillage systems in a field and farmer survey conducted in Saskatchewan in 2003[12].

Min-till or no-till substitutes herbicide use for tillage to varying degrees. However, an analysis of multiple studies found little evidence that min-till or no-till increased herbicide use[14]. A more recent study contradicts that assessment; systems with greater tillage usage in Saskatchewan in 2003 were less likely to use herbicides for the following herbicide application timings: pre- and post-harvest the previous year and pre- and post-crop emergence in the survey year[12]. Twenty-one percent of the area using conventional tillage did not use any herbicides at those timings in the survey year, whereas less than 1% of no-till systems did not receive at least one herbicide application. Fields/farmers that were surveyed for weed resistance in Saskatchewan in 2003 (about 50% of the 370 fields surveyed) were a subset of the 1,010 fields/farmers in the reported general weed survey[12].

In the general weed survey in Saskatchewan in 2003, tillage system interacted with cropping diversity[12]. Summer fallow was more common in systems with conventional tillage and fallow was used by 80% of those surveyed, while only 31% of those surveyed included summer fallow when using no-till systems. A forage crop was most often used in the rotation where conventional tillage was used, accounting for 11% of those surveyed. In these situations, the intensity of tillage may have been more closely associated with the tillage required to terminate forage crops rather than growing annual crops. Conversely, oilseed and pulse crops were more often included in rotations on land where no-till was used. The association of pulse crops with no-till has been previously shown[9]. Overall, 34% of conventional-till area had only one crop type (cereals) planted in 6 years (survey year and previous 5 years), whereas only 5% of no-till area had comparably low crop diversity. Only 16% of the area in conventional-till and min-till systems had three or more crop types included in the rotation, as compared with 47% in no-till systems.

In no-till systems, weed seeds are concentrated on or immediately below the soil surface, compared with a more even distribution in the soil profile of conventional-till systems, with weed distribution depth depending on the depth and intensity of tillage. With no-till, weed seedlings are recruited mainly from weed seeds shed in the previous crop. Therefore, weed seedbank turnover rates are greater in no-till than conventional-till systems. The faster the turnover rate, the faster the development of resistance[1]. If resistance is developing in a field, the proportion of weed seeds produced in the current growing season with resistance will likely be greater than that of older seeds in the weed seed bank. Conventional tillage provides more opportunity for susceptible weed seeds throughout the soil profile to germinate, emerge and thereby dilute or buffer the proportion of resistant individuals in the weed population. Tillage can also reduce weed seedbank turnover rate by promoting dormancy in weed seeds[11]. Greater weed seed bank turnover rate may interact with increased herbicide use in no-till systems on the Prairies to increase the risk of developing herbicide resistance in weed populations.

Thus, some degree of soil disturbance in the cropping system may reduce the risk of HR weeds, either by facilitating a reduction in herbicide use or slowing the rate of weed seed bank turnover. However, time, machinery, and fuel savings usually are more important considerations than risk of weed resistance for farmers utilizing no-till systems. Proponents of no-till cropping systems justifiably cite the sustainability of this tillage system in terms of soil and water conservation, carbon sequestration, and mitigation of greenhouse gas emissions. However, eliminating one element (mechanical) of integrated weed management may expose farmers to an increased risk of weed resistance.

4. Herbicide-use practices

Based on results of a field and farmer survey in Saskatchewan in 1996, the occurrence of group 1 resistance in wild oat was associated primarily with the frequency of group 1 herbicide use[13]. In multi-year surveys in Wheatland County, Alberta, group 2-HR wild oat was associated with recent use of herbicides with that mode of action[4].

Information from the farmer management questionnaire associated with the 2001-2003 field survey indicated that herbicide usage varied by region and cropping system[5]. Two herbicide modes of action most prone to select resistance, groups 1 and 2, continued to be widely and repeatedly used. There was little evidence that farmers were aware of the level of resistance within their fields, but a majority had adopted herbicide rotations to proactively or reactively manage HR weeds. Farmers indicated a high degree of adoption of herbicide group rotation (70-90%, with some variation by province), tank-mixing broadleaf weed herbicides (50-70%), and scouting fields after in-crop herbicide application (63-72%) to assess any developing herbicide resistance[2, 5]. Surprisingly, weed resistance was not associated with any of these practices. This suggests that the rigor or effectiveness of their implementation might be less than required for delaying the development of resistance or that they are ineffective. Because over 95% of farmers in the 2001-2003 survey did not suspect or were unaware of herbicide resistance in weed populations in their surveyed field[5], herbicide-use practices generally were not aimed at controlling suspected or confirmed HR weed biotypes.

5. Other non-herbicide management practices

Triazine resistance in broadleaf weed biotypes in Ontario was associated with manure application[18], presumably due to spread of viable weed seeds back onto land. Based on results of a field and farmer survey in Saskatchewan in 1996, the occurrence of group 1 resistance in wild oat was negatively associated with the extent of implementation of weed sanitation practices that mitigate weed seed spread[13]. Such practices included cleaning equipment when moving between fields, tarping grain trucks, mowing or spraying ditches or uncontrolled weed patches, and applying composted versus fresh manure.

Based on the 2001-2003 survey, the occurrence of wild oat resistance was greater for farmers who identified that weed as most troublesome in the surveyed field than for those who did not. This linkage suggests that farmers, most of whom are unaware of wild oat resistance in their field, are not using effective herbicide chemistries for wild oat control, i.e., they are not avoiding herbicides to which wild oat are resistant. Farmers who ranked competitive crops in first place from the list of cultural weed management practices were less likely to have weed resistance in their surveyed field. However, no significant associations were detected between weed resistance occurrence and ranking of the usefulness of a number of other cultural weed management practices. Moreover, crop residue management did not significantly impact the risk of occurrence of HR weeds.

The results of this study clearly identify cropping system diversity as the basis of proactive weed resistance management. Herbicide-use intensity and diversity are undoubtedly meshed with cropping diversity. These findings support those obtained from a much smaller survey of HR wild oat conducted in southern Alberta in the late 1990s[4], and clearly point the way for farmers who want to reduce their risk of weed resistance. They need only look at the increasing worldwide incidence of glyphosate-resistant weed biotypes, many evolving in no-till, glyphosate-resistant crop monocultures. Therefore, maintaining crop diversity in no-till systems is an essential ingredient for their long-term sustainability.

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